A Study on the Self-Oscillating Mixer

K. D. Park · S. Sakurazawa · H. Arai

Yokohama National University

E-mail : kdpark@arailab.dnj.ynu.ac.jp

Abstract

This paper presents self-oscillating mixer(SOM) with simple structure which includes dc source, a cross type groove, and a three terminal GaAsFET. By using parasitic elements such as cooper wires, IF level of the active antenna is increased. In order to include active device into FDTD analysis, equivalent voltage source are used to substitute for the active device and to describe the voltage-current relationships. This approach is applied to analyze SOM theoretically.

Ⅰ. Introduction

Recently there have been extensive efforts in developing new microwave and millimeter-wave solid-state devices. Due to the advances in device technology, and the fact that the evolving technology is using monolithic microwave integrated circuits(MMICs) for microwave and millimeter -wave applications, active integrated antenna became an area of growing interest[1].

The terminology of "active antenna" means that the active devices are employed in the passive antenna elements to improve antenna performance. The implementation of active devices in passive elements showed several advantages, e.g., increasing the effective length of short antenna, increasing the bandwidth, and improving the noise factor.

Further to these advantages, we have some merits of no need additional mixer and low transmission loss by operating active antenna as Self-Oscillating Mixer(SOM). SOM functions as a mixer in the presence of a RF signal. This RF signal influences the oscillation properties and participates in the frequency conversion with the oscillating signal to generate the IF signal[2].

In this paper, we present SOM having a simple structure which includes dc source for biasing and GaAsFET in the center. However, it has some problems of low IF level and unstable oscillation. To overcome these problems, it has been studied on the increasing of IF level by using parasitic elements. Also, this paper presents the FDTD analysis of SOM based on the voltage-source approach. We use a dual approach that employes voltage sources to represent active devices and generate electro magnetic fields according to Faraday's law.

Ⅱ. Self-Oscillating Mixer

Fig. 1 shows the basic formulation of receiving mixer. Receiving mixer is the circuit which is able to pick up IF signal by adding weak receiving signal and local oscillating signal to nonlinear active device. By adding receiving frequency(L_{RF}) and local oscillating frequency(L_{LO}) to active elements, numerous different frequencies of $mL_{RF} \pm nL_{LO}$(m, n : integer) is generated.

Fig. 2 shows the basic formulation of SOM. The structure of this active antenna is very simple. It is composed of a cross type groove, a dc source, and a GaAsFET soldered on dielectric substrate. The active antenna can be oscillated by establishing dc 3[V] bias voltage. By adjusting parameters of l_g and l_d, different oscillating frequencies is generated. Also, it is able to get IF signal in receiving RF signal by

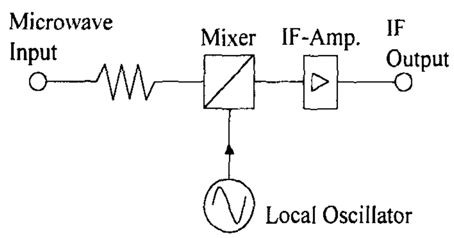

Fig. 1 Basic formulation of receiving mixer

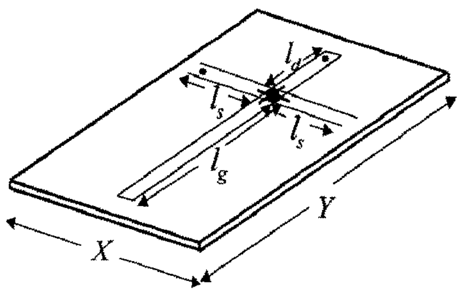

Fig. 2 Basic formulation of SOM

SOM local oscillating frequency.

Fig. 3 shows the experiment system which includes dipole antenna connected signal generator for oscillating and spectrum analyzer for measuring the output of IF. The height of dipole antenna and oscillating frequency are 10[cm], 1.9[GHz], respectively.

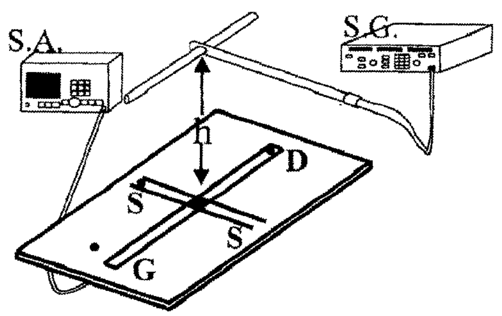

Fig. 3 Experiment System

In order to increase IF level of active antenna, we make many parasitic elements such as cooper wire and then examine conditions for increasing IF level by using them. The form and length of parasitic elements depends on the receiving signal frequency and wave length, respectively. Among available methods for increasing IF level, it is noted that we examine

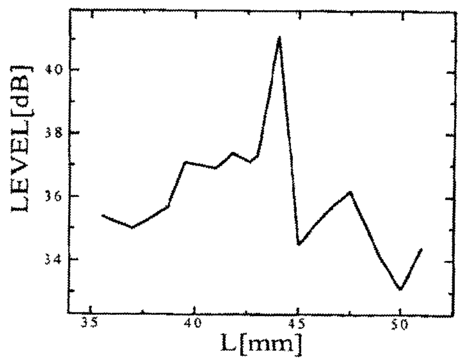

Fig. 5 Relation of L and IF level

about the relation the length of a parasitic element and IF level of active antenna. Fig. 4 shows active antenna installed two parasitic elements. Thorough the relation of L and IF level as shown Fig. 5, IF level is increased by using parasitic elements.

III. Modeling of Nonlinear Active Device

The entire system under consideration contains dc source and GaAsFET active device. In order to include active device into FDTD analysis, the active device can be replaced by equivalent voltage sources in the active region. Through this equivalent circuit, the field quantities in the FDTD algorithm are combined with the circuit quantities in the device model to describe the interaction between the device and electromagnetic fields[3].

To combine with FDTD algorithm, equivalent voltage source are used to substitute for the active device and to describe the voltage-current relationships. Fig. 6 shows voltage source is connected to the ground plane through bias at the source port. The modeling of this nonlinear active device needs to carry out the

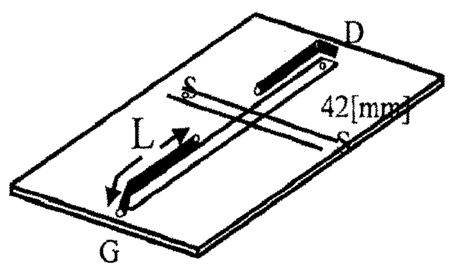

Fig. 4 Installation of two parasitic elements

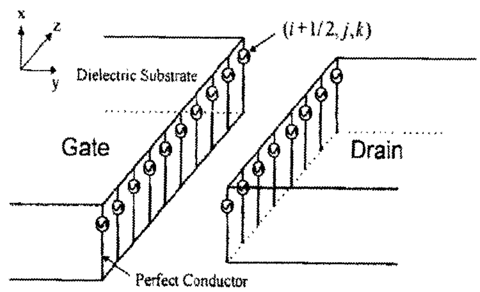

Fig. 6 The positions of the equivalent voltage source emulating active device.

incorporation of the device into the FDTD time-marching algorithm.

Ⅳ. Simulation

The model is applied to analyze an actual self-oscillating mixer, which includes a cross type groove, a dc bias source and a three terminal GaAsFET. The layout of the SOM is depicted in Fig. 7.

The FDTD simulation is performed with uniform grid of space steps $\triangle x=0.4$[mm], $\triangle y=1$[mm], $\triangle z=1$[mm]. The computation domain is divided into uniform meshes of dimensions $304\times67\times108$. The size of the GaAsFET resides in the region of 10[mm] in the direction $\triangle z$. The active device can be viewed as a black box. For this two-port device, two sets of voltage sources are placed at the gate and drain ports as shown Fig. 6. The numbers of voltage sources at the gate and drain ports are ten and eight, respectively. The formulation of incorporating a dc source for biasing into the FDTD algorithm is depicted in [4]. A cross type groove resides in dielectric substrate of two FDTD cells. The signal generator connected dipole antenna is replaced by a delta-gap excitation of $sin(2\pi f t)$, f=1.9[GHz].

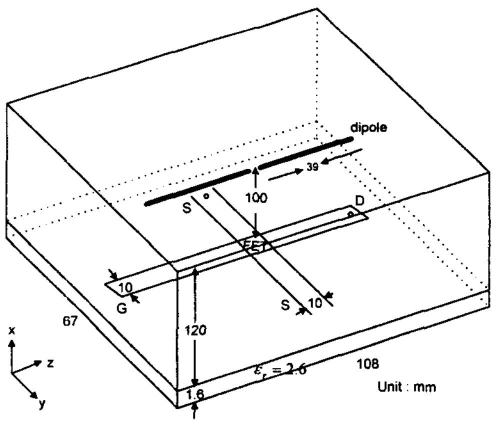

Fig. 7 The layout of SOM

By using the extended FDTD algorithm described above, we simulated above active antenna. Fig. 8 shows the result by taking Fourier transform of the observed time response of electrical level. An observation point is (55, 54) of y-z coordinate in Fig. 7. The result illustrates oscillation at 1.9[GHz] to

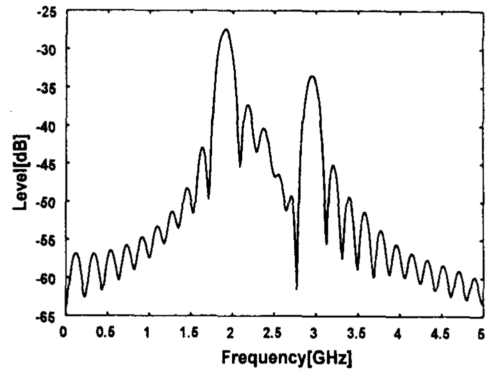

Fig. 8 Calculated output at observation point

dipole antenna and 3[GHz] to dielectric substrate with only a cross type groove. However, IF level which is the difference of receiving frequency and local oscillating frequency is not appeared.

Ⅴ. Conclusion

A IF level of SOM which includes dc source, a cross type, and a three terminal GaAsFET can be increased by using parasitic elements such as cooper wires. In order to incorporate the active device with FDTD algorithm, voltage-source approach is used. This approach is then applied to the analysis of SOM.

References

[1] J. Lin and T. ITOH, "Active Integrated Antennas," IEEE Trans. Microwave Theory Tech., vol. 42, No. 12, pp2186-2194, December 1994.

[2] S. Sakurazawa, "A study on the formation of parasitic elements and gain improvement of self-oscillating mixer," graduation thesis 1999.

[3] C. N. Kuo, R. B. Wu, B. Houshmand, and T. Itoh, "Modeling of Microwave Active Devices Using the FDTD Analysis Based on the Voltage-Source Approach," IEEE Microwave And Guided Wave Letters, vol. 6, No. 5, pp. 199-201, May 1996.

[4] W. Sui, D. A. Christensen, and C. H. Durney, "Extending the two-dimensional FD-TD method to hybrid electromagnetic systems with active and passive lumped elements," IEEE Trans. Microwave Theory Tech., vol. 40, pp.724-730, April 1992.